From Glasma to QCD Phase Boundary

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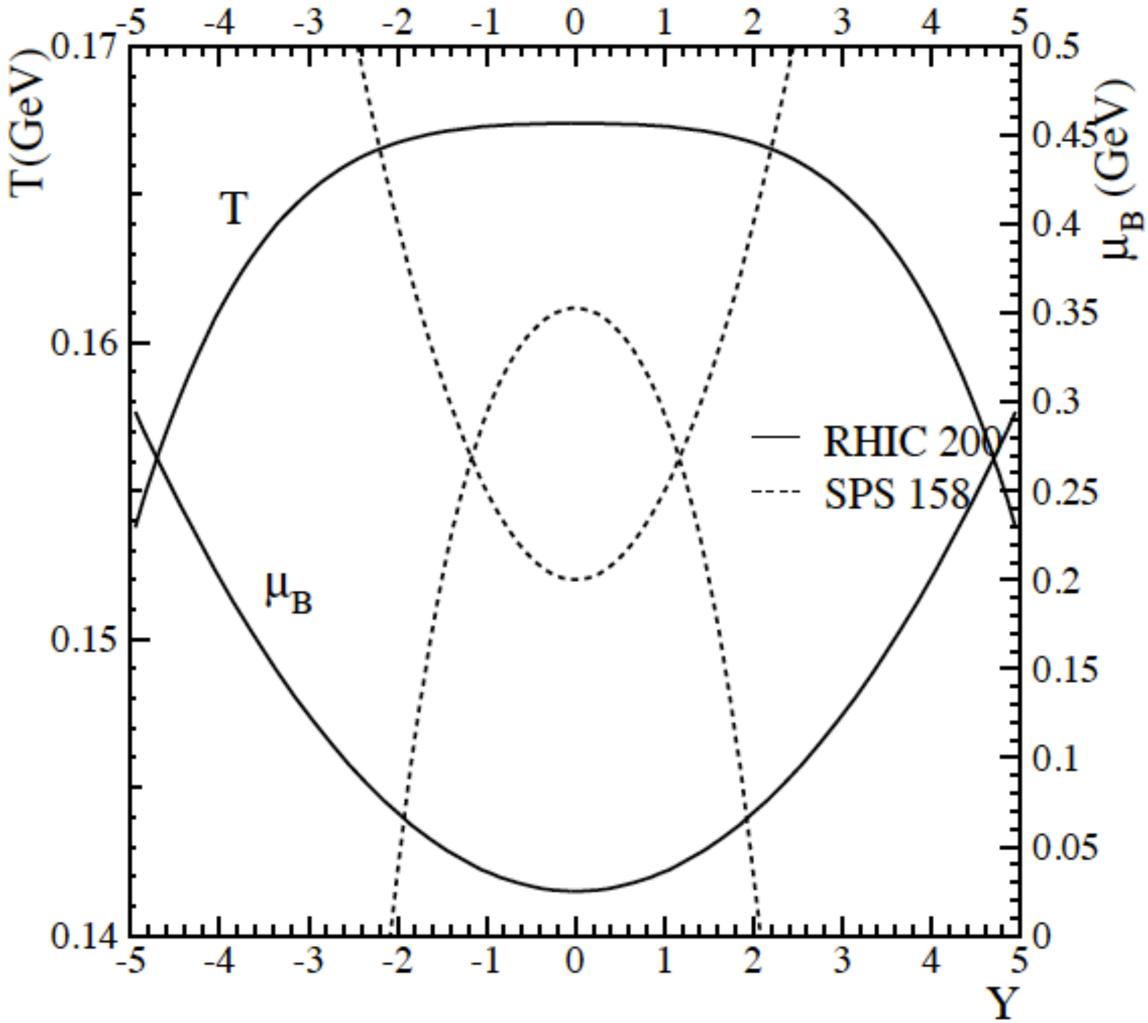
Title given by organizers:

Glasma is a high energy concept so I will concentrate on the various regions of rapidity that can be probed in high energy nuclear collisions Will discuss this in the context of a recent paper by Ming and Kapusta, who have revived interest in this problem.

In principle, it is conceptually simpler to understand the space-time evolution of matter produced in the fragmentation region of an ultra-relativistic nuclear collision than in low energy collisions.

Do such collisions give access to the high baryon number density?

Answer in part by
Beccatini and Cleymans



Appears one is in interesting region of phase diagram for SPS

RHIC?

Good solid angle coverage, fixed target experiments can cover fragmentation region of target, but very hard in collider mode.
However..

Limiting Fragmentation?
Maximum rapidity for RHIC and SPS?

$$Large\ N_c$$

$$T_{dec}$$

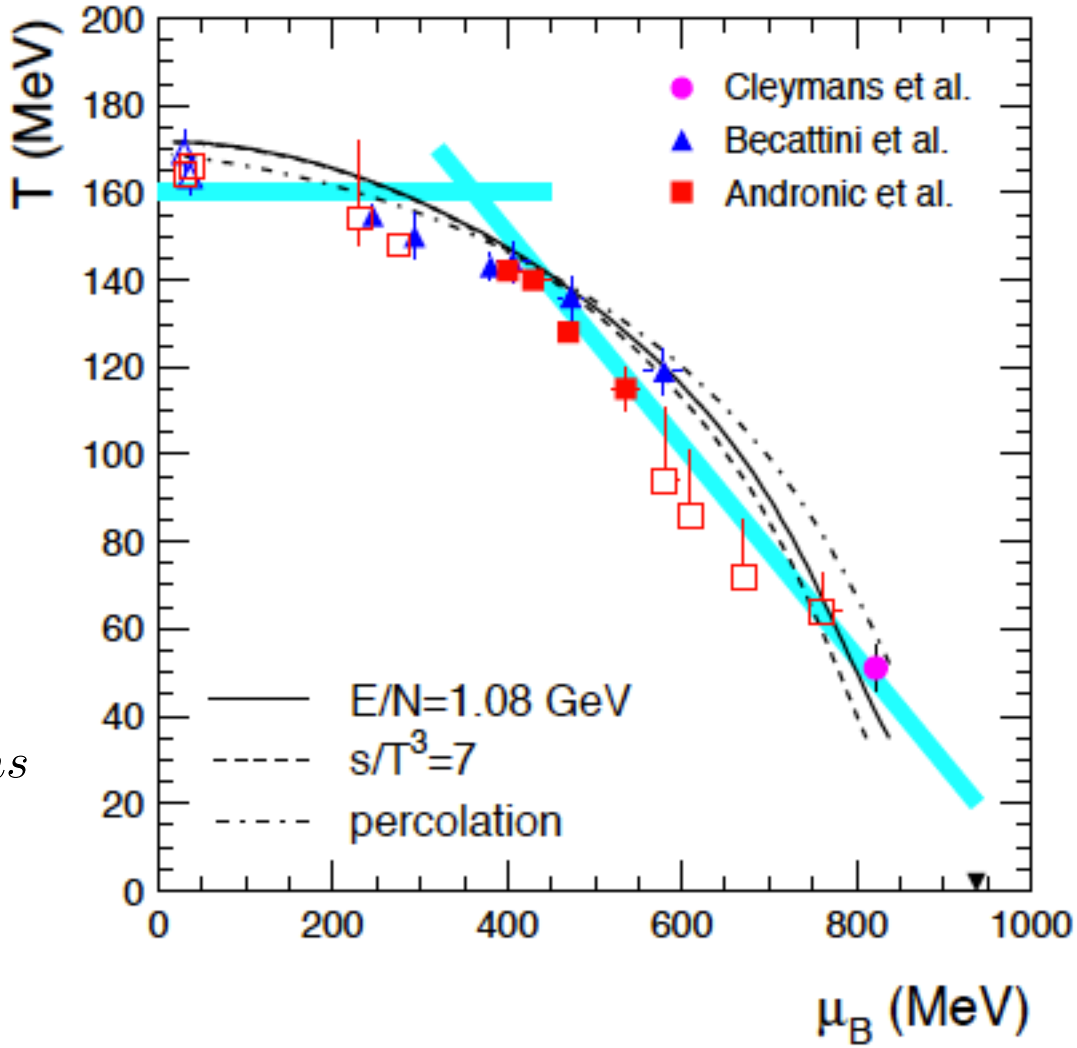
Independent of

$$\mu_B$$

Quarkyonic

$$(M_N - \mu_B)/T \sim cons$$

$$\mu_B = M_n - c\, T$$



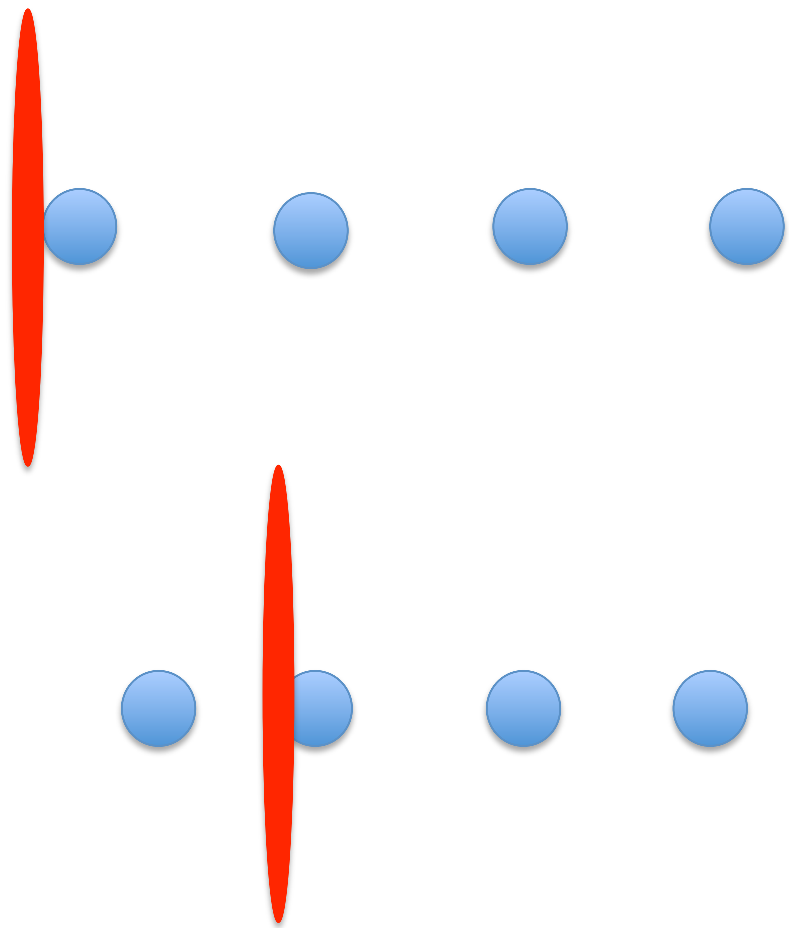
Triple point, critical end point?

$$\mu_B \sim 300 - 500\ MeV$$

$$T \sim 140 - 170\ MeV$$

Why is high energy fragmentation regions somewhat simple?

Anishetty, Koehler and McLerran, Ming and Kapusta



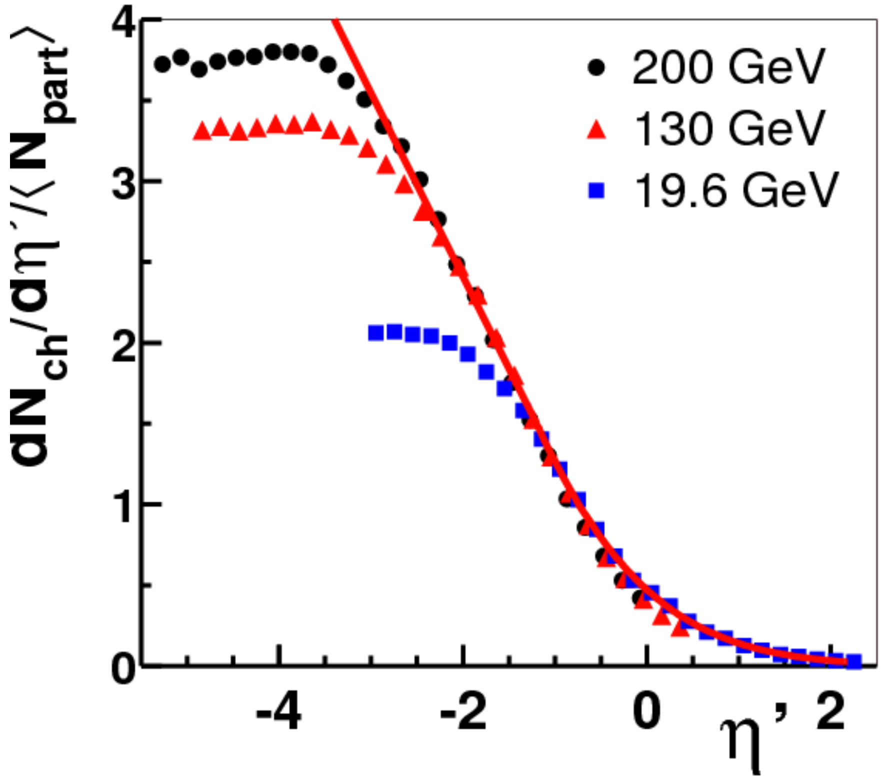
$$\Delta z \sim 1 - v$$

In boosted fame of struck nucleon, compression

$$\Delta z_{comoving} \sim 1/\gamma_{nucleon}$$

The CGC and Limiting Fragmentation:

Empirically, limiting fragmentation works quite well



Phobos Data

The projectile nucleus is dark up to a resolution scale of order the inverse saturation momentum. Therefore the target nucleus is stripped of sea quarks and gluons up to a momentum scale of order this inverse resolution scale. As beam energy increases, there is smaller x probed of the projectile, and momentum scale increases, so there should be some weak breaking of scaling for multiplicity distributions

Although multiplicity distribution approximately scales, average transverse momentum of produced particles is much different. Naïve CGC transverse momentum distribution for gluons is

$$\frac{dN}{dyd^2p_T} \sim cons, \quad p_T < Q_{sat}^{target}$$

$$\frac{dN}{dyd^2p_T} \sim \frac{Q_{sat}^{proj\ 2}}{p_T^2}, \quad Q_{sat}^{target} < p_T < Q_{sat}^{proj}$$

$$\frac{dN}{dyd^2p_T} \sim \frac{Q_{sat}^{proj\ 4}}{p_T^4}, \quad Q_{sat}^{proj} < p_T$$

Albacete, Rodriguez and Nara for comparison with LHCf and better treatment including fragmentation

$$\frac{dN}{dy} \sim Q_{target}^2$$ Does not change up to logarithms

$$< p_T^2 > \sim Q_{proj}^2$$ Is about 100 times bigger at LHC than at RHIC since

$$x_{rhic}^{proj} \sim 10^{-2} \qquad x_{lhc}^{proj} \sim 10^{-9}$$

At LHC, initial conditions are hotter and denser than at RHIC

$$\gamma_{nucleon}^{target} \sim Q^{proj} R_{proj}$$

$$\epsilon_{target}^{nucleons}(t \sim 1\ fm) \sim \mu T^3 \sim QR\ \rho_0$$

$$\epsilon_{target}^{glu}(t \sim 1\ fm) \sim T^4 \sim QR\ \rho_0$$

$$\mu/T$$

Not so rapidly changing?

Needs simulation with realistic hydro evolution to resolve!

Given information about the rapidity distribution of produced nucleons and the rapidity distributions of nucleons and mesons, one directly constructs initial conditions for hydrodynamic expansion

Never need to consider an initial stage where nucleons collide making a fluid of low density matter which produces matter of intermediate density leading to high energy density matter. The situation is like the central region for high LHC and RHIC where we think of the matter as being produced from some initial states of very high energy density matter

Limiting fragmentations tells us that once the projectile nucleus is sufficiently Lorentz contracted little new is gained by higher and higher energy. This requires separation of fragmentation regions of the nuclei or center of mass energies of greater than or of order

30 GEV

For asymptotically large nuclei, there is surely a first principles QCD computation of initial state. CGC?

Ming and Kapusta